

Jan Klimaszewski · Adam Brunke
Derek S. Sikes · Mikko Pentinsaari
Benoit Godin · Reginald P. Webster
Anthony Davies · Caroline Bourdon
Alfred F. Newton

A Faunal Review of Aleocharine Beetles in the Rapidly Changing Arctic and Subarctic Regions of North America (Coleoptera, Staphylinidae)

A Faunal Review of Aleocharine Beetles
in the Rapidly Changing Arctic and
Subarctic Regions of North America
(Coleoptera, Staphylinidae)

Jan Klimaszewski • Adam Brunke •
Derek S. Sikes • Mikko Pentinsaari •
Benoit Godin • Reginald P. Webster •
Anthony Davies • Caroline Bourdon •
Alfred F. Newton

A Faunal Review of
Aleocharine Beetles in
the Rapidly Changing
Arctic and Subarctic
Regions of North
America (Coleoptera,
Staphylinidae)

Jan Klimaszewski
Laurentian Forestry Centre
Natural Resources Canada
Canadian Forest Service
Quebec City, QC, Canada

Adam Brunke
Canadian National Collection of Insects
Agriculture and Agri-Food Canada
Ottawa, ON, Canada

Derek S. Sikes
University of Alaska Museum
Fairbanks, AK, USA

Mikko Pentinsaari 
Centre for Biodiversity Genomics
University of Guelph
Guelph, ON, Canada

Benoit Godin
Whitehorse, YT, Canada

Reginald P. Webster
Charters Settlement, NB, Canada

Anthony Davies
Canadian National Collection of Insects
Agriculture and Agri-Food Canada
Ottawa, ON, Canada

Caroline Bourdon
Laurentian Forestry Centre
Natural Resources Canada
Canadian Forest Service
Quebec City, QC, Canada

Alfred F. Newton
Department of Zoology
Field Museum of Natural History
Chicago, IL, USA

ISBN 978-3-030-68190-6 ISBN 978-3-030-68191-3 (eBook)
<https://doi.org/10.1007/978-3-030-68191-3>

© Her Majesty the Queen in Right of Canada

© Crown 2021, corrected publication 2022

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG. The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To all the little but megadiverse aleocharine beetles for helping us understand the natural world and the processes changing our planet.

Preface

Humans have long struggled to explore and understand the Arctic and Subarctic regions and found these irresistible. By the middle of this century, rising temperature could strip away the Arctic ice and thaw the tundra, affecting humans and our fauna and flora. The thawing tundra will accelerate warming of the climate, affecting people and animals, and putting many species at risk of extinction. An important task is to provide faunal inventory and tools for species identification to have baseline data for future comparisons/monitoring and to help protect and restore species-at-risk habitats. Aleocharine beetles are well represented in the North. However, they are among the most poorly known and difficult-to-identify groups of Coleoptera. Here, we present the first comprehensive synopsis of all known valid aleocharine rove beetle species (Coleoptera, Staphylinidae) from Arctic and Subarctic zones of Canada and Alaska. Two hundred thirty-eight species in 55 genera and 12 tribes are reported. Five new to science species are described. Forty-five new state distribution records for the USA (mainly Alaska) and 108 new provincial and territorial records for Canada (AB, BC, LB, MB, NT, NU, ON, QC, YT) are provided. Every treated species is presented with a diagnosis, including external and genital descriptions. For every species a plate with color habitus image and black and white images of genital structures are provided to aid in identification of species. Collection and habitat data, often new, are presented for each species including information on macrohabitat, microhabitat, collecting period, and collection methods. Keys to species, genera, and tribes are provided. A list of all valid recorded Arctic and Subarctic species with their currently known distribution in North America is presented at the end of the book (Table A.1, in Annex 2). A faunal analysis and discussion of Northern aleocharine beetles in a broader context of North America is provided. Aleocharines as indicator species of environmental changes and the impact of climate change on northern fauna are discussed.

TAXONOMIC SYNOPSIS. The following species are described as new to science: *Atheta (Datomicra) chadburnae* Klimaszewski and Godin, **sp. n.**; *Atheta (Dimetrota) takhini* Klimaszewski and Godin, **sp. n.**; *Hydrosmecta yukonensis* Klimaszewski and Godin, **sp. n.**, *Liparocephalus humblei* Klimaszewski, **sp. n.**; and *Philhygra donnellyana* Klimaszewski, **sp. n.** New synonyms are established as follows (first name being valid): *Atheta allocera* Eppelsheim, 1893 = *Dimetrota campbelli* Lohse, 1990 (= *Atheta*); *Atheta diversa* (Sharp, 1869, orig. *Homalota*) = *Dimetrota regissalmonis*

Lohse, 1990 (=Atheta); *Gyrophaena rugipennis* Mulsant et Rey, 1861 = *G. neonana* SeEVERS, 1951; *Oxypoda robusticornis* Bernhauer, 1907 = *O. madgei* Lohse, 1990; and *Phillygra ripicola* (Hanssen, 1932, orig. Atheta) = *P. ripicoloides* Lohse, 1990. New generic combinations: *Atheta* (*Dimetrota*) *onthophilides* (Newton, 2017), replacement name for preoccupied *Acrotona onthophila* Lohse 1990, a junior secondary homonym in *Acrotona* and *Atheta* of *Atheta onthophila* Cameron 1920; *Bellatheta microptera* (Lohse 1990), orig. *Pseudosipalia microptera* Lohse, in Lohse et al. 1990. A lectotype is designated for Palaearctic *Atheta aeneipennis* (Thomson 1856, orig. *Homalota*), which was determined to be a senior synonym of Palaearctic *A. parapicipennis* Brundin 1954. Identities of *Liogluta trapezicollis* Lohse and *L. vasta* (Mäklin) are revised. A neotype is designated for *Homalota planaris* Mäklin, 1852 (currently *Dinaraea*), and deposited in the CNC.

Corrections to Klimaszewski et al. 2020 (see Annex 3).

Quebec City, QC, Canada	Jan Klimaszewski
Ottawa, ON, Canada	Adam Brunke
Fairbanks, AK, USA	Derek S. Sikes
Guelph, ON, Canada	Mikko Pentinsaari
Whitehorse, YT, Canada	Benoit Godin
Charters Settlement, NB, Canada	Reginald P. Webster
Ottawa, ON, Canada	Anthony Davies
Quebec City, QC, Canada	Caroline Bourdon
Chicago, IL, USA	Alfred F. Newton

The original version of the book was revised: Annex 3 has been updated.
 A correction to the book can be found at
https://doi.org/10.1007/978-3-030-68191-3_21

Acknowledgments

We thank the following institutions supporting this project: Laurentian Forestry Centre; Canadian National Collection of Insects, Arachnids and Nematodes; Centre for Biodiversity Genomics, Guelph, Ontario; and University of Alaska Fairbanks. The first author would like to thank his Director General Dominic St-Pierre and Research Director Elizabeth Gauthier for their support of this project under the Coleoptera Collection program. He would also like to thank his wife, Patricia Corvera, for continuous support at home, particularly during the COVID-19 pandemic, and to his technician, Caroline Bourdon, for her many years of outstanding work and support of his research projects including this book. We thank Greg Breed (University of Alaska Fairbanks) for helpful comments on Chap. 4. Credit for images goes mainly to Sylvain Roberge (LFC) and Caroline Bourdon (LFC). The following curators and individuals provided specimens including types and ordinary specimens, including those from Europe, and we gratefully acknowledge their assistance: Christopher M. Ernst (SFU), Christoffer Fägerström (BMLS), Christopher C. Grinter (CAS), Crystal Maier (FMNH), Jaakko Mattila (ZMH), Marko Mutanen (ZMUO), Floyd Shockley (USNM), and Volker Assing (Hannover, Germany). The fifth author would like to thank his wife Denise Horwood. For over a decade, she has been his enthusiastic partner in countless rove beetles “round-ups.” Her insight into habitat has led to many discoveries. Our thanks to Craig Machtans who provided photographs of habitats in Northwest Territories and Maria Leung and Denise Horwood for habitats in the Yukon Territory. Funding for this project was provided by Natural Resources Canada, University of Alaska, and Alaskan funding agencies for collecting insects.

Contents

1	Introduction	1
	References	2
2	A Historical Review of Research on Aleocharinae of the Arctic and Subarctic Ecoregions of North America and an Overview of the Study Region	3
	Arctic and Subarctic North America	3
	Historical Review of Research on Aleocharinae of the Arctic and Subarctic	3
	References	7
3	Material and Methods	11
	Format	11
	Abbreviations	11
	Institution Codes	12
	Diagnostic Features	12
	External Body Structures Important for Identification	12
	Genital Structures Important for Identification	13
	Microdissections and Preparation of Genital Structures for Examination and Diagnostics	15
	Image Production	16
	DNA Barcoding	16
	Collection Methods and Habitats	18
	Arctic and Subarctic Habitats	21
	References	69
4	Effects of Global Warming on the Distribution and Diversity of Arctic and Subarctic Insects	73
	References	80
5	Aleocharine Beetles as Indicators of Environmental Change	85
	References	89
6	Faunal Analysis and Discussion	91
	Dominant Arctic and Subarctic Aleocharine (ASA) Tribes	91

Ecoregional Differences in Aleocharine Diversity	92
Subarctic Aleocharinae: A Transitional Faunal Between Boreal and Arctic	92
Arctic Aleocharinae: A Fauna at the Extreme	94
Holarctic Species	94
Adventive Species in Subarctic and Arctic North America	95
Future Research and Sampling	95
References	96
7 List of Recorded Arctic and Subarctic Aleocharine Species of North America and Their Composition	99
Family STAPHYLINIDAE Latreille, 1802 (Rove beetles)	99
Subfamily ALEOCHARINAE Fleming, 1821	99
References	105
8 Key to Aleocharinae Tribes of Arctic and Subarctic North America	109
Key to Tribes	109
References	133
9 Tribe Gymnusini Heer, 1839	135
Tribe Gymnusini Heer, 1839	135
Genus <i>Deinopsis</i> Matthews, 1838	136
Genus <i>Gymnusa</i> Gravenhorst, 1806	137
References	153
10 Tribe Aleocharini Fleming, 1821	155
Tribe Aleocharini Fleming, 1821	155
Genus <i>Aleochara</i> Gravenhorst, 1802	155
References	180
11 Tribe Oxypodini C.G. Thomson, 1859	183
Tribe Oxypodini C.G. Thomson, 1859	183
Genus <i>Meotica</i> Mulsant and Rey, 1873	185
Genus <i>Alfocalea</i> Klimaszewski, 2004	186
Genus <i>Calodera</i> Mannerheim, 1830	187
Genus <i>Devia</i> Blackwelder, 1952	189
Genus <i>Gnathusa</i> Fenyes, 1910	189
Genus <i>Hylota</i> Casey, 1906	192
Genus <i>Mniusa</i> Mulsant and Rey, 1875	193
Genus <i>Neothetalia</i> Klimaszewski, 2004	195
Genus <i>Ocyusa</i> Kraatz, 1856	198
Genus <i>Oxypoda</i> Mannerheim, 1830	199
Genus <i>Parocalea</i> Bernhauer, 1902	222
Genus <i>Parocyusa</i> Bernhauer, 1902	223
Genus <i>Phloeopora</i> Erichson, 1837	225
References	272
12 Tribe Tachyusini C.G. Thomson, 1859	275
Tribe Tachyusini C.G. Thomson, 1859	275
Genus <i>Brachyusa</i> Mulsant and Rey, 1873	276

	Genus <i>Dasygnypta</i> Lohse, 1974	277
	Genus <i>Gnypta</i> C.G. Thomson, 1859	278
	Genus <i>Paradilacra</i> Bernhauer, 1909	286
	Genus <i>Tachyusa</i> Erichson, 1837	286
	References	302
13	Tribe Boreocyphini Klimaszewski and Langor, 2011	305
	Tribe Boreocyphini Klimaszewski and Langor, 2011	305
	Genus <i>Boreocypha</i> Klimaszewski and Langor, 2011	305
	References	308
14	Tribe Hypocyphini Laporte, 1835	309
	Tribe Hypocyphini Laporte, 1835	309
	Genus <i>Cypha</i> Leach, 1819	309
	References	312
15	Tribe Myllaenini Ganglbauer, 1895	313
	Tribe Myllaenini Ganglbauer, 1895	313
	Genus <i>Myllaena</i> Erichson, 1837	313
	References	321
16	Tribe Liparocephalini Fenyés, 1918	323
	Tribe Liparocephalini Fenyés, 1918	323
	Genus <i>Amblopusa</i> Casey, 1893	324
	Genus <i>Diaulota</i> Casey, 1893	325
	Genus <i>Paramblopusa</i> Ahn and Ashe, 1995	326
	Genus <i>Liparocephalus</i> Mäklin, 1853	328
	References	337
17	Tribe Homalotini Heer, 1839	339
	Tribe Homalotini Heer, 1839	339
	Subtribe Bolitocharina C.G. Thomson, 1859	339
	Genus <i>Leptusa</i> Kraatz, 1856	340
	Subtribe Gyrophaenina Kraatz, 1856	341
	Genus <i>Gyrophaena</i> Mannerheim, 1830	341
	(Subgenus <i>Gyrophaena</i> Mannerheim, 1830)	342
	Genus <i>Silusa</i> Erichson, 1837	346
	References	356
18	Tribe Placusini Mulsant and Rey, 1871	359
	Tribe Placusini Mulsant and Rey, 1871	359
	Genus <i>Placusa</i> Erichson, 1837	359
	References	369
19	Tribe Athetini Casey, 1910	371
	Tribe Athetini Casey, 1910	371
	Subtribe Athetina Casey, 1910	372
	Genus <i>Acrotona</i> Thomson, 1859	374
	Genus <i>Adota</i> Casey, 1910	376
	Genus <i>Aloconota</i> C.G. Thomson, 1858	378
	Genus <i>Amischa</i> C.G. Thomson, 1858	379

Genus <i>Atheta</i> C.G. Thomson, 1858 [sensu lato]	381
(Subgenus <i>Alaobia</i> C.G. Thomson, 1858)	382
(Subgenus <i>Atheta</i> C.G. Thomson, 1858)	384
(Subgenus <i>Bessobia</i> C.G. Thomson, 1858)	390
(Subgenus <i>Datomicra</i> Mulsant and Rey, 1873b)	391
(Subgenus <i>Dimetrota</i> Mulsant and Rey, 1873a)	393
(Subgenus <i>Dimetrota</i>) <i>Incertae sedis</i>	424
(Subgenus <i>Lamiota</i> Casey, 1910)	425
(Subgenus <i>Microdota</i> Mulsant and Rey, 1873a)	426
(Subgenus <i>Pseudota</i> Casey, 1910)	433
(Subgenus <i>Rhagocneme</i> Munster, 1922)	435
(Subgenus <i>Tetropla</i> Mulsant and Rey, 1873b)	436
Genus <i>Atheta</i> <i>Incertae Sedis</i>	437
Genus <i>Bellatheta</i> Roubal, 1928	439
Genus <i>Boreophilia</i> Benick, 1973	440
Genus <i>Boreostiba</i> Lohse, 1990	449
Genus <i>Dinaraea</i> C.G. Thomson, 1858	455
Genus <i>Dochmonota</i> C.G. Thomson, 1859	458
Genus <i>Earota</i> Mulsant and Rey, 1873b	460
Genus <i>Hydrosmecta</i> C.G. Thomson, 1858	461
Genus <i>Liogluta</i> C.G. Thomson, 1858	463
Genus <i>Lypoglossa</i> Fenyés, 1918	473
Genus <i>Mocyta</i> Mulsant and Rey, 1873b	475
Genus <i>Philhygra</i> Mulsant and Rey, 1873a	479
Genus <i>Schistoglossa</i> Kraatz, 1856	491
(Subgenus <i>Boreomorpha</i> Klimaszewski and Webster, in Klimaszewski et al. 2009)	492
(Subgenus <i>Schistoglossa</i> Kraatz, 1856)	493
Genus <i>Strigota</i> Casey, 1910	495
Genus <i>Tarphiota</i> Casey, 1893	498
Genus <i>Trichiusa</i> Casey, 1893	499
Athetini with Subtribe Affiliation Uncertain	500
Genus <i>Paragoniusa</i> Maruyama and Klimaszewski, 2004	500
References	639
20 Tribe Lomechusini Fleming, 1821	645
Tribe Lomechusini Fleming, 1821	645
Genus <i>Zyras</i> Stephens, 1835	645
References	648
Correction to: A Faunal Review of Aleocharine Beetles in the Rapidly Changing Arctic and Subarctic Regions of North America (Coleoptera, Staphylinidae)	C1
Annex 1	649
Annex 2	691
Annex 3	701
Index	705



Introduction

1

The ecosystems of the Arctic and Subarctic of northern Canada and Alaska are rapidly changing due to faster than expected climate warming and thawing permafrost, reshaping the land and releasing carbon gases. In these regions, temperatures are warming at more than three times the global average. Northern ecosystems (including tundra, forests and shrublands) are being profoundly impacted, affecting the way of life for residents. Ecosystem integrity and function is dependent in large part on how constituent species adapt to environmental stressors (e.g., warming climate, melting permafrost and sea ice). Much attention has focused on species traditionally utilized by residents of the North (e.g., plants, mammals, birds, and fish). However, the vast majority of biodiversity is represented by less conspicuous and non-iconic species. Although relatively unseen, under-considered, and poorly studied, these species (e.g., invertebrate animals, fungi, lichens) play critical roles that contribute to the functioning of healthy ecosystems. Society must also be concerned about this more cryptic biodiversity as these organisms, to a large degree, drive these ecosystems from the bottom up. Understanding how climate change is affecting biodiversity in its broadest sense will provide a more comprehensive understanding of shifts in northern ecology and the implications for human well-being. The responses of vertebrates and plants to climate change are not a proxy for how other groups of organisms are impacted.

Unfortunately, the biodiversity of invertebrates, fungi, lichens, etc. in the North is poorly documented, which provides an enormous challenge for documenting and predicting change in these assemblages. We propose a start to remedy this problem, focusing on aleocharine rove beetles. Aleocharine beetles, the largest group of rove beetles (Coleoptera), are being used in many Canadian Forest Service and other national and international projects as indicators of environmental change. Many species are specialists restricted to specific soil/litter and forest microhabitats, while some are generalists and others are open habitat specialists. They fill many ecological niches and as such are good indicators for some other insect groups sharing similar habitats. Aleocharine beetles are a proven ecological indicator group with species reacting to climate variables such as humidity and temperature (Klimaszewski et al. 2008, Pohl et al. 2007, 2008). In Canada, the majority of aleocharine beetle species (over 600 spp.), were treated by the first author and collaborators, setting a foundation for ecological work on this group (Klimaszewski et al. 2018, 2020). Most are species from southern, central, eastern and western Canada. However, the fauna of the Subarctic and Arctic regions of Canada remains poorly known and is poorly documented. Much material has been collected as a result of various studies and sampling in Arctic and Subarctic regions, and this represents an enormous effort and investment, yet

this material has not been identified nor ecological information synthesized, such that the full value of that investment has not been reaped. We provide new knowledge for this group of insects in Northern Canada and Alaska and synthesize existing information, in order to provide the baseline information and diagnostic tools to facilitate future ecological studies and assessment of the susceptibility of these organisms to climate change. We gathered and studied all available specimens and records on species of aleocharine occurring in the study area (see Chap. 2), creating a comprehensive baseline data set for these species. This information is largely extracted from specimens currently housed in collections in Canada and USA (Alaska), and from the literature. Comprehensive ecological work on vertebrates and plants in the North, including responses to climate change, is possible because identification tools are available for these species. However, this is often not the case for various groups of arthropods. Until diagnostic tools are available, many different arthropod groups will continue to be relegated to the realm of human ignorance. If we want to fully understand the ecological implications of climate change, consideration must be given to a broad cross-section of biodiversity, including the lesser-known groups that comprise the vast majority of species and play an important role in ecological

functioning of the ecosystems. One such group is the aleocharine beetles. Our work will provide information and diagnostic tools to open up a new frontier of enquiry into Canada's and Alaskan northern biodiversity.

References

- Klimaszewski J, Langor D, Work TT, Hammond JHE, Savard K (2008) Smaller and more numerous harvesting gaps emulate natural forest disturbances: a biological test case using rove beetles (Coleoptera, Staphylinidae). *Divers Distrib* 14:969–982
- Klimaszewski J, Webster RP, Langor DW, Brunke A, Davies A, Bourdon C, Labrecque M, Newton AF, Dorval J-A, Frank JH (2018) Aleocharine rove beetles of eastern Canada (Coleoptera, Staphylinidae, Aleocharinae): a glimpse of megadiversity. Springer, Cham. xvi + 902 pp
- Klimaszewski J, Hoebeker ER, Godin B, Davies A, Perry KI, Bourdon C, Winchester N (2020) Aleocharine rove beetles of British Columbia: a hotspot of Canadian biodiversity (Coleoptera, Staphylinidae). Springer, Cham. xvi + 631 pp
- Pohl GR, Langor DW, Spence JR (2007) Rove beetles and ground beetles (Coleoptera: Staphylinidae, Carabidae) as indicators of harvest and regeneration practices in western Canadian foothills forests. *Biol Conserv* 137:294–307
- Pohl GR, Langor DW, Klimaszewski J, Work TT, Paquin P (2008) Rove beetles (Coleoptera: Staphylinidae) in northern Nearctic forests. *Can Entomol* 140:415–436

A Historical Review of Research on Aleocharinae of the Arctic and Subarctic Ecoregions of North America and an Overview of the Study Region

Arctic and Subarctic North America

We define the arctic and subarctic regions in Canada and Alaska as comprising the following level II ecoregions as defined by CEC (2018) (see Fig. 2.1): Arctic Cordillera (1.1), all tundra regions (2.1–2.4), all taiga regions (3.1–3.4), the Hudson Plains (4.1) and the Boreal Cordillera (6.1). The study region includes Alaska (United States) and at least the north part of all Canadian provinces except the Maritimes. As the majority of samples from Labrador have been taken near the border and transitional zone between Taiga Shield (3.4) and the milder Softwood Shield ecoregion (5.1), we have included all Labrador records in the present study but excluded those from ecoregion 5.1 in the historical review (below) and faunal analysis of Chap. 6. Species known so far only from region 5.1 and southward are noted in the comments section of each species account. For a more detailed, regional description of each ecoregion, see Chap. 3.9.

Historical Review of Research on Aleocharinae of the Arctic and Subarctic

Taxonomic research on Nearctic Aleocharinae, beginning in 1830 (Say 1830), has left a nomenclaturally complex but undeniably valuable legacy that has been reviewed in detail by

Klimaszewski et al. (2018) and Klimaszewski et al. (2020). During much of this time, the Arctic and Subarctic aleocharine (ASA) fauna of North America was virtually unknown. This was likely due to a paucity of material available to early taxonomists, as access to interior wilderness was impossible or extremely difficult. Just three localities, all coastal or up-river from the coast, appear in the historical literature: Nome and Unalaska, AK, and Glenora, BC. As could be expected, six of only seven ASA taxa published before 1979 were described in the massive treatments of Aleocharinae by T. L. Casey (1906, 1910, 1911): *Atheta nomadica* Casey, 1910 (AK: Nome) (syn.: *Atheta graminicola* (Gravenhorst, 1806)); *Atheta surgens* (Casey, 1910) (BC: Glenora); *Baryodma glenorana* Casey, 1906 (BC: Glenora) (syn.: *Aleochara castaneipennis* Mannerheim, 1843); *Baryodma mannerheimi* Casey, 1906 (BC: Glenora) (syn.: *Aleochara castaneipennis* Mannerheim, 1843); *Gnypeta brevicornis* Casey, 1906 (BC: Glenora); *Homalota granulata* Mannerheim, 1846 (AK: Unalaska) (syn.: *A. graminicola*; *Paradilacra glenorica* Casey, 1910 (BC: Glenora) (syn.: *P. densissima* (Bernhauer, 1909)). Two species of *Oxyptoda* described by Casey (1893) based on material from Glenora BC, *O. glenorae* and *O. impressa*, are of uncertain taxonomic status because their type specimens are missing genitalia (Klimaszewski et al. 2020). These species are not treated herein. As with much of his species-

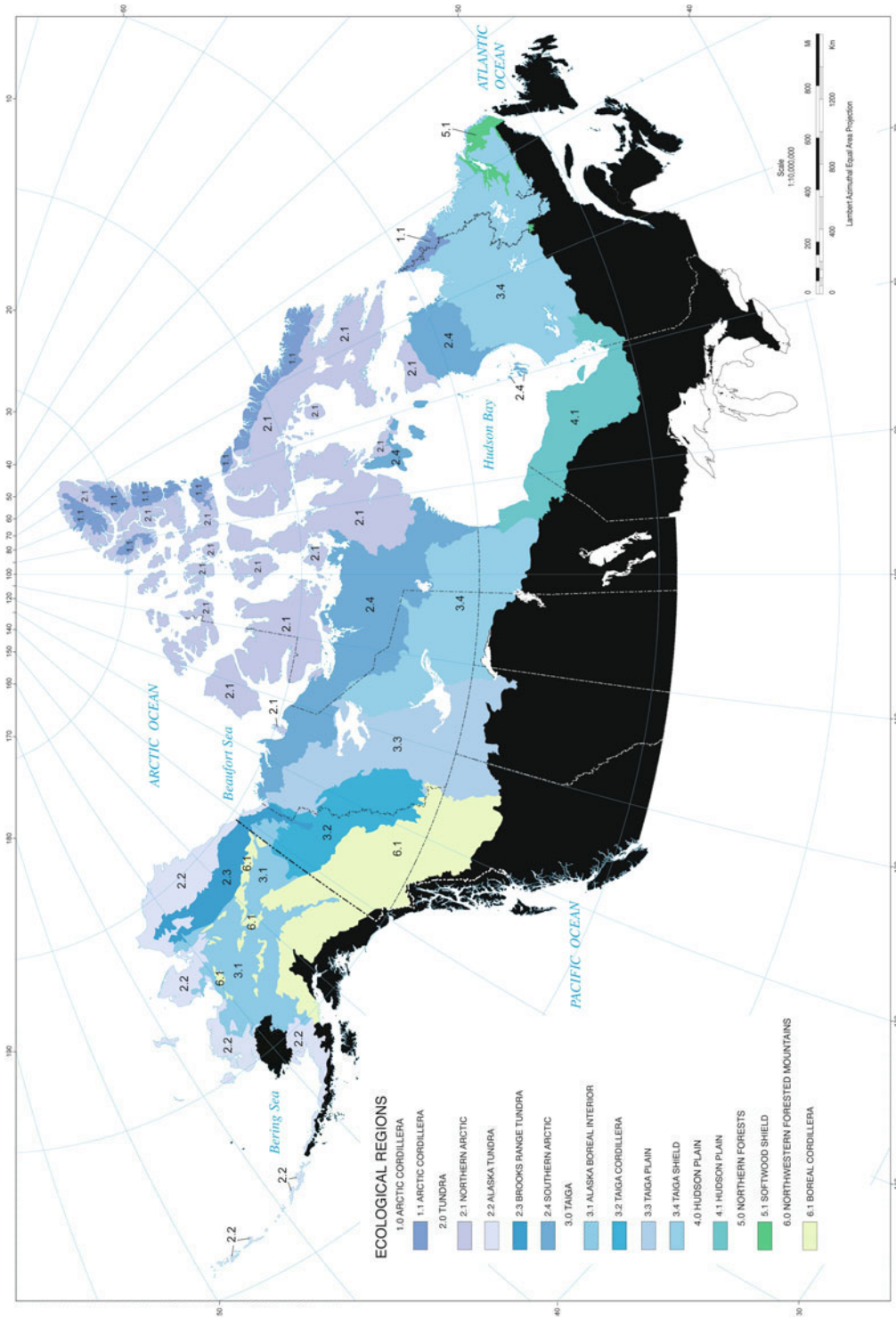


Fig. 2.1 Arctic and subarctic ecological regions (level II) of North America. Coloured area represents the study region. Map modified from Level II Ecoregions of North America (CEC 2018)

level taxonomic work on Coleoptera (reviewed in detail in Klimaszewski et al. 2020), Casey's underestimation of intraspecific morphological differences led to the later synonymy of all but two of his ASA taxa.

This long period of limited scientific progress was later countered with a large number of collecting expeditions to the study area. The Canadian Hudson Strait Expedition in 1927 (material from Port Burwell, NU; as QC in Lohse et al. 1990)) was the first to yield specimens of ASA taxa (F. Johansen). Material was also collected by W.J. Brown (CNC) from AK, MB and NT during the 1930s–1950s. During the 1940s–1980s, much of the material was collected by Canadian scientists, including those participating in the Northern Insect Survey (1947–1961) (Freeman 1959), which was conducted by staff at the Canadian National Collection of Insects, Arthropods and Nematodes

(CNC) (Freeman 1959): A. Smetana, J.M. Campbell, J.R. Vockeroth, E. Becker, J.F. McAlpine, J.G. Chillcott, W.R.M. Mason, J.E.H. Martin, M. Wood and G.E. Shewell (all CNC; AK, LB, MB, NT, NU, QC, YT). Other significant Canadian collectors included R. E. Leech and B.S. Heming (University of Alberta, Edmonton, Alberta, Canada; AK, NT, YT), and A. and A. Morgan (University of Waterloo, Ontario, Canada; QC). Other material was collected by R. Madge in the 1960s (London, UK; AK) and C.H. Lindroth during the 1950s (Lund University, Sweden; AK).

The first taxonomic study to incorporate this wealth of aleocharine material was Klimaszewski (1979), later supplemented by Klimaszewski (1982a), which treated the world fauna of Gymnusini including ASA genera *Deinopsis* and *Gymnusa* (Fig. 2.2). Klimaszewski (1982b) revised the Nearctic *Myllaena*, which included

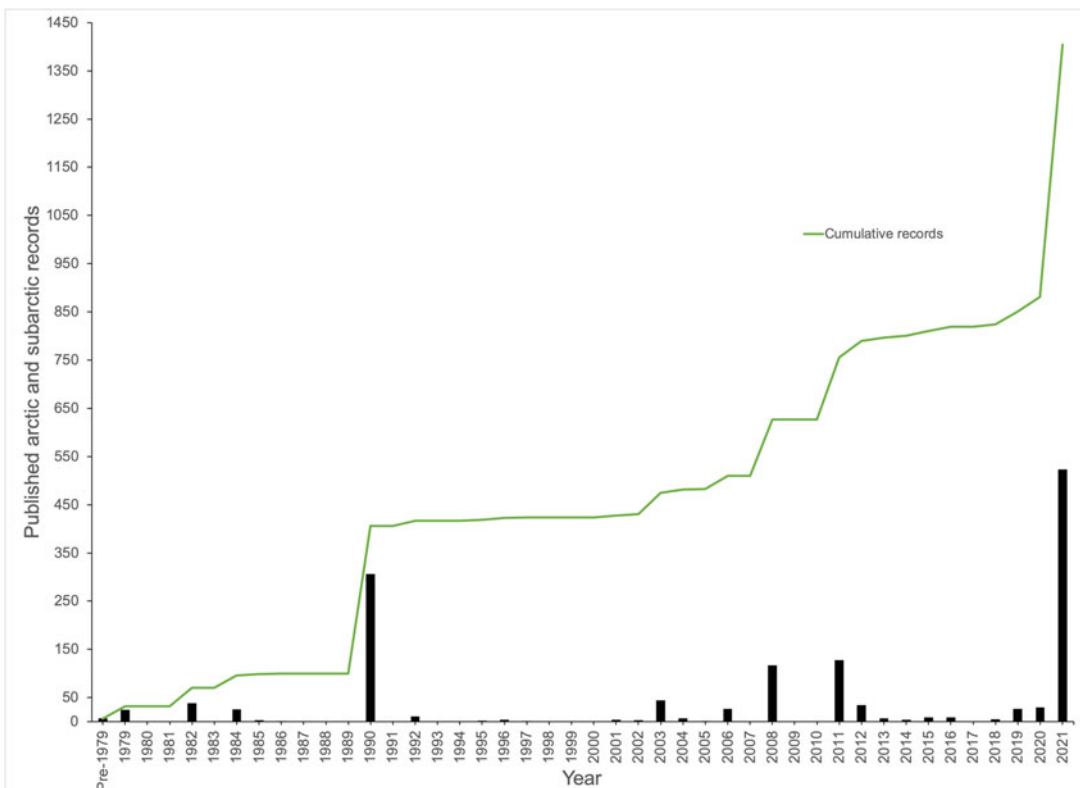


Fig. 2.2 Published records of Arctic and Subarctic Aleocharinae (Staphylinidae) over time. Included records are geographically distinct (to two decimal places, as given in decimal degrees) for a given species. Labrador records

in ecoregion 5.1 (CEC 2018) are not considered and records from 2021 were entirely derived from the present contribution

three widespread species occurring in the study region. Shortly thereafter, a comprehensive revision of the Nearctic *Aleochara* by Klimaszewski (1984) brought another modest increase in the number of ASA records. Lohse and Smetana (1985) revised the type specimens of tribes Oxypodini and Athetini described from north-western North America by Mannerheim (1843, 1846) and Mäklin (1852, 1853). In this paper the authors newly reported genera *Dinaraea* and *Liogluta* from the study region. While not a major contributor of ASA records as nearly all species were described from Sitka, AK (excluded here), this work formed an important taxonomic foundation for many species which were later discovered to occur in the study region.

Arguably, the most significant contribution to knowledge of ASA was the treatment of tribes Aleocharini, Oxypodini and Athetini by Lohse et al. (1990) (Fig. 2.2). Drawing upon the considerable material collected by the abovementioned expeditions and the previous study by Lohse and Smetana (1985), twenty genera and 73 species from the Arctic and Subarctic were treated, of which two genera and 50 species were described as new to science. Over 300 data points across the various species were published for the study region. An important achievement of this work was the recognition of thirteen species described from the Palaearctic region as naturally Holarctic species occurring also in North America. Their restricted taxonomic concept of the large and morphologically heterogeneous genus *Atheta* was useful and has been incorporated in most modern studies of Nearctic Aleocharinae thereafter as subgenus *Atheta* (including the present work). Campbell and Davies (1991) provided a checklist of the Aleocharinae recorded in Canada and Alaska (later updated by Bousquet et al. 2013), serving as an important foundation for the abundance of taxonomic studies on Aleocharinae still to come.

There was almost no research on ASA taxa during the 1990s after Lohse et al. (1990). Hoebeke (1992) reviewed the Nearctic *Lypoglossa* and reported this genus from the study region for the first time. Ahn and Ashe (1995), Ahn (1996a, b) and Ahn (1997) reviewed

the seashore-dwelling genera *Amblopusa*, *Diaulota*, *Liparocephalus*, *Paramblopusa* and *Tarphiota*, and provided a few records from the study region. Eleven years later, a revision of *Placusa* (Placusini) was published by Klimaszewski et al. (2001), which included some widespread species occurring in the forested parts of the study zone. Gusarov (2002) revised the Nearctic species of *Earota* and provided the first record of the genus from the study region. Gusarov (2003) revised a large number of aleocharine type specimens, including those of Lohse et al. (1990) and synonymized five of these species. Here, the genera *Dochmonota* and *Schistoglossa* were reported for the first time from the study area. Gusarov (2003) also examined Arctic and Subarctic CNC specimens not included by Lohse et al. (1990), and contributed approximately 43 new data points across the various treated ASA taxa. In the same year, Klimaszewski et al. (2003) recorded *Silusa* (Homalotini: Silusina) from the study region for the first time. Shortly thereafter, Gusarov (2004) revised the species of *Lypoglossa*, and Klimaszewski and Pelletier (2004) revised the genera of the *Ocalea* group (Oxypodini), including the description of ASA genera *Neothetalia* and *Alfocalea*. In a review of the Canadian genera of the *Zyras* group (Lomechusini), Klimaszewski et al. (2005) reported the relatively thermophilic tribe from the study region for the first time (*Zyras obliquus*, far northern AB). In the following year, Klimaszewski et al. (2006) revised the species of diverse *Oxypoda* in Canada and Alaska, including a significant number of ASA species, and newly reported *Hylota* from the study region. Pašnik (2006) reported *Tachyusa* (Tachyusini) from the study region for the first time.

A combination of two 'northern-themed' studies in 2008 resulted in the second major increase in knowledge of ASA taxa (Fig. 2.2): a revision of the diverse northern genus *Gnypeta*, with many Holarctic species (Klimaszewski et al. 2008a), and a paper by Klimaszewski et al. (2008b), which reported new species and new records from YT and AK. The latter recorded the tribe Hypocyphtini (*Cypha*), subtribe Gyrophaenina of

Homalotini (*Gyrophaena*) and genus *Amischa* (Athetini) from the study region for the first time, with locality data. In the same year Majka and Klimaszewski (2008) reported two new jurisdictional records for the study region.

Several years later, a comprehensive treatment of the Aleocharinae of Newfoundland and Labrador was published (Klimaszewski et al. 2011), which included many records from the Taiga Shield (ecoregion 3.4) of Labrador (Fig. 2.1). This study represents the third major increase in data for ASA taxa (Fig. 2.2) as a result of the authors incorporating an abundance of newly collected samples from the region. The authors newly reported genera *Deinopsis*, *Paragoniusa* and *Parocysa* from the study region. One year later, a second study on the Yukon aleocharine fauna was published (Klimaszewski et al. 2012), including first records of *Brachyusa*, *Calodera* and *Strigota* for the study region. Studies of biodiversity patterns in northern Canada by Ernst and Buddle (2013, 2015) brought new tundra and taiga locality records (NT and NU) for seven ASA taxa. Klimaszewski et al. (2013) revised the species of subcortical genus *Dinaraea* and provided a few relevant localities for the region, while the northern genera *Gnathusa*, *Mniusa* and *Ocyusa* were revised by Klimaszewski et al. (2014). Faunistic studies of Canadian Aleocharinae by Klimaszewski et al. (2015) and Webster et al. (2016) published new records of ASA taxa, including the first record for the study region of *Trichiusa* in the latter paper. The wet litter-associated species of *Liogluta*, with several ASA species, were revised by Klimaszewski et al. (2016) and later, the aleocharine fauna of eastern Canada was comprehensively reviewed by Klimaszewski et al. (2018), with a few new distributional records of ASA taxa.

Most recently, a revision of the northern genus *Boreophilia*, containing many Holarctic species was published (Klimaszewski et al. 2019). In addition to providing records from newly collected material, the authors also corroborated species concepts for many Holarctic taxa using DNA barcodes. A year later, a comprehensive review of Aleocharinae of BC was published, which

contributed a number of new records from the study region based mostly on newly collected material from AK, NT, YT and northern BC. These records included the first evidence of *Meotica* in the study region. In the same year, Ahn et al. (2020) reported the intertidal species *P. eoa* from the Nearctic region (AK) and Yoo and Ahn (2020) provided several records of *Amblopusa breviceps* Casey from the study area.

Based mostly on newly collected material deposited in UAM, LFC and CBG and some previously unexamined material in CNC, we here contribute over 500 new data points on ASA species. These combine with previous data to form 1404 geographically distinct, species-level records that form the core of the present work as a whole. Recent collecting efforts associated with the above collections are described in detail in Chap. 3 and include the Canadian National Parks Malaise Program (<http://biodiversitygenomics.net/projects/cnp/>) and the Arctic BIOSCAN project (<https://arcticbioscan.ca/>). Although the present work contributes a considerable amount of new data, Arctic and Subarctic North America is vast and remains inadequately sampled (see Chap. 6). Many ASA species are known only from one or two localities and still little is known of the biogeography of most of these taxa. The present work as a whole provides a synthesis of existing knowledge and morphological identification tools. We hope that these will contribute to a better understanding of the changes happening to our fragile northern ecoregions, through the implementation of biodiversity and ecological impact studies that include this diverse subfamily.

References

- Ahn KJ (1996a) A review of *Diaulota* Casey (Coleoptera: Staphylinidae: Aleocharinae), with description of a new species and known larvae. *Coleopt Bull* 50:270–290
- Ahn K-J (1996b) Revision of the intertidal aleocharine genus *Tarphiota* (Coleoptera: Staphylinidae). *Entomol News* 107:177–185
- Ahn K-J (1997) A review of *Liparocephalus* Mäklin (Coleoptera: Staphylinidae: Aleocharinae) with descriptions of larvae. *Pan Pac Entomol* 73(2):79–92

- Ahn KJ, Ashe JS (1995) Revision of the intertidal aleocharine genus *Amblopusa* Casey and description of the new genus *Paramblopusa* (Coleoptera: Staphylinidae). *J N Y Entomol Soc* 103:138–154
- Ahn K-J, Sikes DS, Klimaszewski J (2020) *Paramblopusa eoa* Ahn and Maruyama (Coleoptera: Staphylinidae: Aleocharinae), distribution range extension to Alaska. *Coleopt Bull* 74(2):324–326
- Bernhauer M (1909) Neue Aleocharini aus Nordamerika. (Col.) (4. Stück.). *Deutsche Entomologische Zeitschrift* 1909(4):515–528
- Bousquet Y, Bouchard P, Davies AE, Sikes DS (2013) Checklist of beetles (Coleoptera) of Canada and Alaska: second edition. *Pensoft Series Faunistica* No. 109. Pensoft, Sofia, Moscow, 402 p
- Campbell JM, Davies A (1991) Family Staphylinidae rove beetles. In: Bousquet Y (ed) Checklist of beetles of Canada and Alaska. Publication 1861/E, Research Branch, Agriculture Canada, Ottawa, pp 86–124. vi + 430 pp
- Casey TL (1893) Coleopterological notices. V. *Ann N Y Acad Sci* 7:281–606
- Casey TL (1906) Observations on the staphylinid groups Aleocharinae and Xantholinini, chiefly of America. *Trans Acad Sci St Louis* 16(6):125–434
- Casey TL (1910) New species of the staphylinid tribe Myrmedoniini. In: *Memoirs on the Coleoptera*. I. New Era Printing Co., Lancaster, PA, pp 1–183. 205 pp
- Casey TL (1911) New American species of Aleocharinae and Myllaeninae. In: *Memoirs on the Coleoptera*. II. The New Era Printing Co., Lancaster, PA, pp 1–245. 259 pp
- Commission for Environmental Cooperation (CEC) (2018) Terrestrial ecoregions – Level II ecoregions. <http://www.cec.org/north-american-environmental-atlas/terrestrial-ecoregions-level-ii/>. Accessed 8 September 2020
- Ernst CM, Buddle CM (2013) Seasonal patterns in the structure of epigeic beetle (Coleoptera) assemblages in two subarctic habitats in Nunavut, Canada. *Can Entomol* 145:171–183
- Ernst CM, Buddle CM (2015) Drivers and patterns of ground-dwelling beetle biodiversity across northern Canada. *PLoS One* 10:122163
- Freeman T (1959) The Canadian northern insect survey, 1947–57. *Polar Record* 9(61):299–307. <https://doi.org/10.1017/S0032247400066006>
- Gusarov VI (2002) A revision of Nearctic species of the genus *Earota* Mulsant & Rey, 1874 (Coleoptera: Staphylinidae: Aleocharinae). *Zootaxa* 92(1):16
- Gusarov VI (2003) Revision of some types of north American aleocharines (Coleoptera: Staphylinidae: Aleocharinae), with synonymic notes. *Zootaxa* 353:1–134
- Gusarov VI (2004) A revision of the genus *Lypoglossa* Fenyès, 1918 (Coleoptera: Staphylinidae: Aleocharinae). *Zootaxa* 747:1–36
- Hoebcke ER (1992) Taxonomy and distribution of the athetine genus *Lypoglossa* Fenyès (Coleoptera: Staphylinidae: Aleocharinae) in North America, with description of a new species. *J N Y Entomol Soc* 100:381–398
- Klimaszewski J (1979) A revision of the Gymnusini and Deinopsini of the world: Coleoptera, Staphylinidae, Aleocharinae, No. 25. Agriculture Canada, Research Branch. Monograph No. 25, 169 pp
- Klimaszewski J (1982a) Studies of Myllaenini (Coleoptera: Staphylinidae, Aleocharinae): 1. Systematics, phylogeny, and zoogeography of Nearctic *Myllaena* Erichson. *Can Entomol* 114(3):181–242
- Klimaszewski J (1982b) A revision of the Gymnusini and Deinopsini of the world (Coleoptera: Staphylinidae). Supplementum 2. *Can Entomol* 114(4):317–335
- Klimaszewski J (1984) A revision of the genus *Aleochara* Gravenhorst of America north of Mexico (Coleoptera: Staphylinidae, Aleocharinae). *Mem Ent Soc Can* 129. [2] + 211 pp
- Klimaszewski J, Pelletier G (2004) Review of the *Ocalea* group of genera (Coleoptera, Staphylinidae, Aleocharinae) in Canada and Alaska: new taxa, bionomics, and distribution. *Can Entomol* 136:443–500
- Klimaszewski J, Pelletier G, Germain C, Hebert C (2001) Diversity of *Placusa* (Coleoptera: Staphylinidae: Aleocharinae) in Canada, with descriptions of two new species. *Can Entomol* 133(1):1–47
- Klimaszewski J, Pohl G, Pelletier G (2003) Revision of the Nearctic *Silusa* (Coleoptera, Staphylinidae, Aleocharinae). *Can Entomol* 135(2):159–186
- Klimaszewski J, Pelletier G, Maruyama M, Hlaváč P (2005) Canadian species of the *Zyras* group of genera and review of types from America north of Mexico (Coleoptera, Staphylinidae, Aleocharinae). *Rev Suisse Zool* 112(3):703–733
- Klimaszewski J, Pelletier G, Germain C, Work T, Hébert C (2006) Review of *Oxyopoda* species in Canada and Alaska (Coleoptera, Staphylinidae, Aleocharinae): systematics, bionomics, and distribution. *Can Entomol* 138(6):737–852
- Klimaszewski J, Savard K, Pelletier G, Webster R (2008a) Species review of the genus *Gnypeta* Thomson from Canada, Alaska and Greenland (Coleoptera, Staphylinidae, Aleocharinae): systematics, bionomics and distribution. *ZooKeys* 2:11–84
- Klimaszewski J, Godin B, Pelletier G, Savard K (2008b) Six new species and records of aleocharine beetles from the Yukon and Alaska (Coleoptera: Staphylinidae: Aleocharinae). *Can Entomol* 140:265–291
- Klimaszewski J, Langor D, Pelletier G, Bourdon C, Perdreau L (2011). Aleocharine beetles (Coleoptera, Staphylinidae) of the province of Newfoundland and Labrador, Canada. *Pensoft Series Faunistica* No. 98. Pensoft, Sophia-Moscow, 313 pp
- Klimaszewski J, Godin B, Bourdon C (2012) Further contributions to the aleocharine fauna of the Yukon

- Territory, Canada (Coleoptera, Staphylinidae). *ZooKeys* 186:207–237
- Klimaszewski J, Webster RP, Langor DW, Bourdon C, Jacobs J (2013) Review of Canadian species of the genus *Dinaraea* Thomson, with descriptions of six new species (Coleoptera, Staphylinidae, Aleocharinae, Athetini). *ZooKeys* 327:65–101
- Klimaszewski J, Webster RP, Langor DW, Bourdon C, Hammond HEJ, Pohl GR, Godin B (2014) Review of Canadian species of the genera *Gnathusa* Fenyès, *Mniusa* Mulsant & Rey and *Ocyusa* Kraatz (Coleoptera, Staphylinidae, Aleocharinae). *ZooKeys* 412:9–40
- Klimaszewski J, Godin B, Langor D, Bourdon C, Lee S-I, Horwood D (2015) New distributional records for Canadian Aleocharinae (Coleoptera, Staphylinidae), and new synonymies for *Trichiusa*. *ZooKeys* 498:51–91
- Klimaszewski J, Webster RP, Langor DW, Sikes D, Bourdon C, Godin B, Ernst C (2016) A review of Canadian and Alaskan species of the genus *Liogluta* Thomson, and descriptions of three new species (Coleoptera, Staphylinidae, Aleocharinae). *ZooKeys* 573:217–256
- Klimaszewski J, Webster RP, Langor DW, Brunke A, Davies A, Bourdon C, Labrecque M, Newton AF, Dorval J-A, Frank JH (2018) Aleocharine rove beetles of eastern Canada (Coleoptera, Staphylinidae, Aleocharinae): a glimpse of megadiversity. Springer, Cham. xvi + 902 pp
- Klimaszewski J, Sikes DS, Brunke A, Bourdon C (2019) Species review of the genus *Boreophilina* Benick from North America (Coleoptera, Staphylinidae, Aleocharinae, Athetini): systematics, habitat, and distribution. *ZooKeys* 848:57–102
- Klimaszewski J, Hoebeke ER, Godin B, Davies A, Perry KI, Bourdon C, Winchester N (2020) Aleocharine rove beetles of British Columbia: a hotspot of Canadian biodiversity (Coleoptera, Staphylinidae). Springer, Cham. xvi + 631 pp
- Lohse GA, Smetana A (1985) Revision of the types of species of Oxypodini and Athetini (sensu Seevers) described by Mannerheim and Mäklin from North America (Coleoptera: Staphylinidae). *Coleopt Bull* 39(3):281–300
- Lohse GA, Klimaszewski J, Smetana A (1990) Revision of Arctic Aleocharinae of North America (Coleoptera: Staphylinidae). *Coleopt Bull* 44(2):121–202
- Majka CG, Klimaszewski J (2008) New records of Canadian Aleocharinae (Coleoptera: Staphylinidae). *ZooKeys* 2:85–114
- Mäklin FW (1852) [New species and notes]. In: Mannerheim, C.G.: Zweiter Nachtrag zur Käefer-Fauna der Nord-Amerikanischen Laender des Russischen Reiches. *Bulletin de la Société Impériale des Naturalistes de Moscou* 25(2):283–372
- Mäklin FW (1853) [New species and notes]. In: Mannerheim, C.G.: Dritter Nachtrag zur Käefer-Fauna der Nord-Amerikanischen Laender des Russischen Reiches. *Bulletin de la Société Impériale des Naturalistes de Moscou* 26(3):95–273
- Mannerheim CG (1843) Beitrag zur Käefer-fauna der Aleutischen Inseln, der Insel Sitkha und Neu-Californiens. *Bulletin de la Société Impériale des Naturalistes de Moscou* 16(2):175–314
- Mannerheim CG (1846) Nachtrag zur Käefer-Fauna der Aleutischen Inseln und der Insel Sitkha. *Bulletin de la Société Impériale des Naturalistes de Moscou* 19:501–516
- Pašník G (2006) A revision of the World species of the genus *Tachyusa* Erichson, 1837 (Coleoptera, Staphylinidae: Aleocharinae). *Zootaxa* 1146:1–152
- Say T (1830) Descriptions of new species of North American insects, and observations on some already described. *New Harmony* 1–41
- Webster RP, Klimaszewski J, Bourdon C, Sweeney JD, Hughes CC, Labrecque M (2016) Further contribution to the Aleocharinae (Coleoptera, Staphylinidae) fauna of New Brunswick and Canada including description of 27 new species. In: Webster, R.P., Bouchard, P., Klimaszewski, J. (Eds) *The Coleoptera of New Brunswick and Canada: providing baseline biodiversity and natural history data*. *ZooKeys* [Special Issue] 573:85–216
- Yoo I-S, Ahn K-J (2020) Discovery of a new intertidal species, *Amblopusa vancouverensis* from Vancouver Island, Canada with notes on *Amblopusa brevipes* Casey (Coleoptera, Staphylinidae, Aleocharinae). *Zootaxa* 4803:505–514



Format

The classification of taxa used herein selectively follows concepts expressed by Seevers (1978), Klimaszewski (1979, 1982, 1984, 2018, 2020), Lohse et al. (1990), Ashe (2001), Gusarov (2003, 2011), Elven et al. (2011, 2012), Pašnik (2010), Bouchard et al. (2011), Schülke and Smetana (2015), and Yamamoto and Maruyama (2017). Distributional records and bionomic information (e.g., habitat associations, collection dates, collecting methods) are based on published records and on specimens in the collections of Laurentian Forestry Centre, the Canadian National Collection of Insects, Arachnids and Nematodes, the collection of University of Alaska, Centre for Biodiversity Genomics and the private collections of B. Godin (BGC) and R. Webster (RWC). This bionomic data often includes information from areas not treated by our book (see Chap. 2) for widespread taxa but should still be relevant to collecting these species. In the case of unpublished records, we provide specimen data under the respective species. Only records considered to be reliable are listed. Latitude/longitude data originally in degrees/minutes format on labels have been converted to decimal degrees.

ZooBank Registration

The present work has been registered in ZooBank, under the following identifier:

urn:lsid:zoobank.org:pub:08B3D0FD-6270-464C-9AE6-4427E5349A7D.

Abbreviations

Additional abbreviations are used in the main text and tables to indicate new records: **NPR** (New Provincial Record), **NTR** (New Territorial Record), **NSR** (New State Record), and **BOLD** (The Barcode of Life Data System).

Jurisdictions in boldface are included in Arctic/Subarctic North America, as defined in this work. We report separately on Newfoundland and Labrador even though together they constitute one province. Roughly, species occurring in LB, NT, NU, YT, and the northern parts of AB, BC, MB, ON, QC, and AK (excluding the Marine West Coast Forest ecozone) are included in this treatment (see Fig. 2.1).

AB **Alberta**
AK **Alaska**
BC **British Columbia**

LB	Labrador
MB	Manitoba
NB	New Brunswick
NF	Newfoundland
NS	Nova Scotia
NT	Northwest Territories
NU	Nunavut
ON	Ontario
PE	Prince Edward Island
QC	Quebec
SK	Saskatchewan
YT	Yukon Territory

State abbreviations for the United States of America follow those of the United States Postal Service.

Institution Codes

BGC	Benoit Godin private collection, Whitehorse, Yukon, Canada
BMLS	Biological Museum (Entomology), Lund, Sweden
CBG	Centre for Biodiversity Genomics, University of Guelph, Guelph, Ontario, Canada
CNC	Canadian National Collection of Insects, Arachnids, and Nematodes, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.
FMNH	Integrative Research Center, The Field Museum of Natural History, Chicago, Illinois, United States of America
LFC	Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, R. Martineau Insectarium, Quebec City, Quebec, Canada.
NBP	Northern Biodiversity Program, a collaborative research initiative.
NoFC	Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta, Canada.
RWC	Reginald Webster (private) collection, Charters Settlement, New Brunswick, Canada.
SFU	Simon Fraser University, Burnaby, British Columbia, Canada.

UAM	University of Alaska Museum Insect Collection, Fairbanks, Alaska, United States of America.
USNM	United States National Museum, Washington, DC, United States of America.
ZMH	Finnish Museum of Natural History, Zoological Museum, Helsinki, Finland.
ZMUO	Zoological Museum, University of Oulu, Oulu, Finland.

Diagnostic Features

Most of the text below regarding diagnostic features is taken from Klimaszewski et al. (2018, 2020). It is important that readers of this book studying the aleocharine fauna of the North have all the information accessible in one source, thus increasing efficiency when working with this complex group. Aleocharine beetles are highly diverse taxonomically, morphologically (Fig. 3.3a–l), and ecologically. Significant challenges with aleocharine species identification are due to the poor state of knowledge of many genera still (e.g., *Acrotona*, *Amischa*, *Atheta*) and the lack of comprehensive diagnostic tools. These are the main obstacles to understanding species richness, assemblage composition, and ecological roles of aleocharines in ecosystems of the North. There are many species, often forming groups of cryptic species, which are externally similar, especially in the large tribes Aleocharini, Athetini, and Oxypodini.

External Body Structures Important for Identification

The terminology used herein follows that used by previous authors (Benick and Lohse 1974; Seevers 1978; Klimaszewski 1979, 1984; Klimaszewski et al. 2018, 2020; Lohse et al. 1990; Ashe 2001; Gusarov 2003). The body length of aleocharine beetles ranges from 1.0–13.0 mm (typically 3.0–5.0 mm) and habitus forms are diverse (Fig. 3.3a–l), reflecting different

adaptations to a variety of microhabitats. They range from somewhat flat (e.g., *Dinaraea*, *Placusa*) to subcylindrical (e.g., some *Leptusa*), and from robust (e.g., *Aleochara*, *Gymnusa*, and *Oligota*) to slender (e.g., *Atheta*, *Myllaena*, and *Meotica*). The term forebody refers to head, pronotum, and elytra as a combined structure. The most important body structures used in identification of aleocharines are illustrated (Fig. 3.4). These relate to the **head** (Fig. 3.4): frontal suture, genae (postocular area, temples), infraorbital carina, neck; **antennae** (Fig. 3.4): proportion of length to width ratio of different antennomeres, length of antennae; **mouthparts** (Fig. 3.5a–f): labrum, labium, maxillae, labial palps, and ligula; **prothorax** (Figs. 3.4, 3.6): pubescence pattern, hypomeron (visible or not visible in lateral view of pronotum), pro-, meso- and metaventrites and their intercoxal processes, isthmus, and coxae; **elytra** (Fig. 3.4): size and shape, pubescence pattern, length of elytral suture, shape of basal margin, and presence or absence of lateral emargination; **abdomen** (Figs. 3.2, 3.7a–e) [10-segmented, position indicated by Roman numerals starting at the base; when describing features of the “first visible tergites” in the keys and diagnoses, we are referring to the basal segments following morphological segments I and II which are reduced and largely hidden by the elytra; segments IX and X are modified; transverse impressions of basal tergites (I–IV), structures inside impressions, and shape of the apical margin of male tergite VIII, and female tergite and sternite VIII]; **legs** (Fig. 3.4): tarsal formula and length and proportions of the tarsomeres of the hind tarsus.

Genital Structures Important for Identification

The morphological diversification of the genitalia, particularly the shape of the median lobe of the aedeagus and its internal sac structures, including flagellum and internal sclerites (structures), morphology and macro-setal pattern on the apical lobe of parameres, and morphology of the spermatheca, likely have played an important role in aleocharine evolution. These

morphological features vary in different species and are generally the structures most important for species- and genus-level identification. The three-lobed aedeagus of aleocharines (median lobe, and two complex lateral lobes called parameres), is the most distinctive feature of the entire subfamily, and constitutes a synapomorphy for this group (Klimaszewski et al. 2018, 2020).

Aedeagus (Fig. 3.8a–d) The male copulatory organ consists of the median lobe (penis = bulbus+tubus) (Fig. 3.8a–b), and the two parameres (Fig. 3.8c–d).

Median lobe of aedeagus (Figs. 3.8a–b, 3.9a–i) This is a tubular, sclerotized, intromittent organ with an enlarged basal portion called the *bulbus* (Fig. 3.8a–b), and a narrow apical portion, subcylindrical or trough-like, called the *tubus* (Fig. 3.8a–b). The tubus is slender in most, and narrow towards the apex. The more or less narrow, basal or median part of lateral edges of the tubus are extended dorsally in Athetini/Lomechusini and form a complete or incomplete arched structure called the *athetine bridge* (Seevers 1978). The shape of the tubus, and particularly its apical portion in lateral view, varies from species to species and is a valuable diagnostic feature (Fig. 3.9a–i). The subspherical bulbus has a small, ventral round opening, the *foramen mediale*, which is an entrance for the ejaculatory duct, the *ductus ejaculatorius*, and one or more projections, the larger called *crista apicalis* or external carina of the bulbus. The *crista apicalis* provides attachment for the muscles connecting the median lobe and the two condylites of the parameres (Fig. 3.8c–d). The internal space of the bulbus contains a complex of mainly dorso-ventral muscles attached internally to the base of the bulbus and to the dorsal mobile compressor plate that is oval and weakly sclerotized in most. Contraction or expansion of the longitudinal and dorso-ventral muscle complexes are directly or indirectly responsible for creation of hydrostatic pressure that results in eversion or retraction of the *internal sac* and its associated internal structures (e.g., sclerites, membranous structures, and flagellum). The *flagellum* (also known as the *virga* or copulatory piece)

(Fig. 3.8a–b) is a short or moderately-to-extremely elongate tubular structure (e.g., some *Aleochara*, *Oxypoda*) that can be narrow or broad, and it has a swollen basal part connected with the ejaculatory duct. The internal sac membranes frequently bear numerous spinules, denticulate plates, and other structures to aid in retention of the sac in the *vulva* (female copulatory tract). During eversion of the internal sac, the internal sclerites and flagellum are extended (everted) exteriorly filling the internal space of the female *vulva* and allowing safe transfer of sperm, or packages of sperm contained in spermatophores, with the aid of the flagellum. The internal sac is withdrawn by a set of longitudinal muscles that originate on the proximal surface of the base of the bulb. The structures and function of the internal sac were previously explained and illustrated for *Aleochara curtula* by Peschke (1978).

The ventral side of the median lobe of the aedeagus is considered to be the side of the bulb containing the foramen mediale, the entrance of the ductus ejaculatorius, and the adjacent ventral side of the tubus of the median lobe with the internal sac and its structures (this part is referred to as the parameral side in Gusarov 2003); the opposite side is referred to as the dorsal part.

Parameres (Fig. 3.8c–d) These are the tactile orientation organs, which enable the male to find the tip of the female abdomen just before copulation, using the setal pattern on the female abdomen as a guide (Peschke 1978). There are two symmetrical parameres, one on each side of the median lobe of the aedeagus, which are attached to the crista apicalis (represented by one, two or several carinae) of the bulb of the median lobe by a complex system of muscles. Each paramere is subdivided into a *paramerite* and a narrowly elongate *condylite*. The paramerite is the main part of the paramere, and consists of a narrow apical lobe bearing a few macrosetae arranged in a particular pattern specific to different genera (Seevers 1978). Attached to the paramerite is a semimembranous *velar sac* bearing microribbings, and the posterior, slit-shaped structure delimited from the apical portion by a weakly sclerotized strip (Seevers 1978;

Klimaszewski 1984). The morphology of the paramere and the setal pattern of the apical lobe of the paramerite provide diagnostic characters at the generic and higher taxonomic levels.

Spermatheca (*receptaculum seminis*) (Figs. 3.8e, 3.10a–l) This is the female genital organ for storing and perhaps selecting sperm (Peschke 1978; Dybas and Dybas 1981). The spermatheca consists of a usually bulbous capsule and narrower and short neck connected to a tubular stem and a valve with thin and membranous, weakly sclerotized seminal canal (*ductus spermathecae*), which connects the spermatheca to the *vulva* and serves to transport sperm. The seminal canal is not considered to be a part of the spermatheca (Klimaszewski 1984). The capsule is a spherical or tubular structure that may be straight or bent, and bears apical invaginations of various shapes and sizes (Fig. 3.10a–l). The stem may be a simple narrow tube or more complex and subdivided into an elongate chamber and a narrower duct. The shape of the spermatheca varies from species to species and is valuable for species separation. In some genera (e.g., *Acrotona*, *Amischa*, some *Atheta*, *Gnypeta*, *Liogluta*, and *Mocyta*) the shape of the spermatheca may be a better diagnostic character than the shape of the median lobe of the aedeagus.

Terminalia (Fig. 3.7a–e) The terminalia herein refer to the male and female tergite VIII and sternite VIII (Fig. 3.7e) and the *pygidium*, the latter consisting of 2–3 modified terminal segments closing the end of the abdomen (Fig. 3.7a–e). Tergite VIII and sternite VIII provide useful additional morphological features for species level diagnostics. These structures can be elongate, subquadrate, or transverse and can have varying pubescence patterns. The *antecostal suture* is located subparallel to the base of tergite VIII and sternite VIII. The antecostal suture may be separated by a wide or narrow distance from the base of the disc and may be straight or sinuate in different species. The apical margin of tergite VIII of males is highly modified in many groups of aleocharines, and particularly in athetines, and often bears teeth, denticles, and other projections

or emarginations, which provide important taxonomic identification features (Fig. 3.7e). The structure of the pygidium is slightly different between males (Fig. 3.7a–b) and females (Fig. 3.7c–d). In the male, the pygidium consists of tergite X, accompanied on both sides by tergite IX (completely subdivided or connected by a narrow dorsal strip), which is extended ventrally into two posterior narrow ventral struts (Fig. 3.7a–b). Ventrally located between the subdivided male tergite IX is a narrowly oval and flat structure which is regarded as the modified sternite IX (Fig. 3.7b). The pygidium of the female is generally similar to that of the male but is lacking ventral struts and an elongate sternite IX (Fig. 3.7c–d). The shape and pubescence pattern of tergite X is diagnostic for some species and genera. Specimens can be sexed by examination of the ventral part of the pygidium for presence (male) or absence (female) of the apical portion of sternite IX, which is present in males as a median rounded lobe (Fig. 3.7b).

Microdissections and Preparation of Genital Structures for Examination and Diagnostics

Identifying aleocharine species and genera can be challenging due to the small size of most specimens and minute size of many distinctive characters, coupled with a vast number of valid taxa (Ashe 2001; Hanley and Ashe 2003; Klimaszewski et al. 2018, 2020). There are many species, often forming groups of sibling species, which are externally similar, especially in the large tribes Athetini (e.g., *Atheta*), and Oxypodini (e.g., *Oxypoda*), and Homalotini (e.g., *Gyrophaena*). Thus, properly dissected genital structures (median lobe of aedeagus, parameres, spermatheca, and tergite VIII and sternite VIII of both sexes) carefully mounted in Canada balsam on plastic microslides for examination, are indispensable for identification of the majority of species and therefore essential for serious work in aleocharine systematics. The methodology of dissecting aleocharine species mouthparts is sufficiently described by Hanley

and Ashe (2003) and is not discussed here because mouthparts are usually not essential for species identification.

Dissection and Dehydration (for Illustrations see Klimaszewski et al. 2020)

With the aid of a stereoscopic microscope, specimens are best dissected in water (room temperature), placed in a microscope depression slide (commercially available slides with impressions used for blood analysis). The abdomen is held in place by forceps while a hooked or straight minuten pin, mounted in a commercially available handle, is inserted between abdominal segment VII and VIII and pulled to dislodge the terminal segments from the rest of the abdomen. The genital structures (aedeagus or spermatheca) are usually inside the dislodged apical part of the abdomen but sometimes may remain in the basal part of the abdomen and should be removed from there. The dislodged apical part of the abdomen is dissected further by removing tergite VIII and sternite VIII from the pygidium using dissecting needles and then breaking the lateral internal muscles that fix the discs in place and pulling the sclerites apart. Subsequently, the aedeagus or spermatheca are also removed and detached from other structures so that tergite VIII, sternite VIII, aedeagus (or spermatheca), and pygidium are separated from each other. Remnants of muscles attached to structures may be removed mechanically using dissecting needles while structures are immersed in water or alternatively structures may be cleared in cold 10% potassium hydroxide for 1–4 min to digest the soft tissues and then washed in water. The aedeagus needs further dissection by removing the parameres from the median lobe using dissecting needles to break the muscles connecting the condylite of the paramere with the *crista apicalis* of the bulbus of the median lobe. All dissected structures need to be washed in clean water, transferred to 75% ethanol for about one minute and then to 100% ethanol for dehydration for about 1–2 min before mounting. Structures should then be mounted in Canada balsam on a celluloid microslide attached to the pin holding the card-mounted body of the dissected specimen. Celluloid microslides are

commercially available in different sizes; the size appropriate for Aleocharinae is 4.5 mm × 11 mm or 6.5 mm × 14.0 mm. One source of celluloid slides is: Entomowinkler—insects, entomological books and supplies, Dittesgasse 11, 1180 Wien, Austria (winkler@entowinkler.at). For beginners it is best to practice dissection on some unimportant specimens, starting with larger specimens.

The genital structures should be mounted on microslides in a consistent pattern of arrangement to facilitate easy comparison of homologous structures on different microslides. We follow the following arrangement of structures on the slide: median lobe of aedeagus in lateral view or spermatheca in right upper corner; separated parameres situated below the median lobe on the right side; tergite VIII in left upper corner, sternite VIII below tergite VIII, and pygidium below sternite VIII. For thinning Canada balsam, we use xylene or non-toxic terpineol, both commercially available. It is important to note that, at first, only a thin layer of Canada balsam is placed on a microslide to prevent floating of structures into undesirable positions. After the first layer of Canada balsam with the genital structures placed in their optimal position on a microslide is dried (after two days), a second layer of Canada balsam can be added to completely, but without excess, cover the structures. We regularly use the above procedure and we find it facilitates the microscopic examination of genital structures and their photography. The advantage of this system is that the dissected specimen and the genital structures are on the same pin in the collection instead of being stored in two separate collections which can be easily misplaced or lost. This approach is also superior to using genitalia vials which take up more room on the pins, may damage structures when taken out of the vial, and requires more handling time.

Image Production

Images of the entire body and the genital structures were taken using an image processing system (Nikon SMZ 1500 stereoscopic

microscope; Nikon Digital Camera DXM 1200F, and Adobe Photoshop software). Images of the dorsal aspects of the head, pronotum, elytra, abdomen, legs and antennae were taken separately in the horizontal plane (except for the head image, which was taken while in a natural position) and fused together in Adobe Photoshop. Images of tergite VIII or sternite VIII that were damaged during dissection were ‘repaired’ by digitally duplicating the undamaged portion using Adobe Photoshop software. For details and illustrations see Klimaszewski et al. (2020).

DNA Barcoding

DNA barcoding (Fig. 3.11a–f) was proposed as a molecular approach to species identification in 2003 (Hebert et al. 2003). Species identification based on DNA sequences was not novel in itself, but the idea of standardization of genomic regions for this purpose across multiple taxa caught wind and has grown into a massive, global effort (<https://ibol.org/>). The 658 base pair fragment of the mitochondrial cytochrome c oxidase I gene (COI) initially proposed by Hebert et al. (2003) has been firmly established as the standard DNA barcode region for animals. Although the species-level resolution of this region is not perfect, DNA barcoding often allows the identification of e.g., immature stages, damaged specimens, or morphologically very similar sibling species, which are impossible to identify with certainty based on morphological characters. Males and females of species with pronounced sexual dimorphism can be difficult to associate with one another in the absence of direct observations of copulation, but these associations can be established through barcoding (Slowik and Blagoev 2012; Corley and Ferreira 2017). DNA barcode data are increasingly used in taxonomic revisions as an additional line of evidence and for initial sorting of the material into putative species (Butcher et al. 2012; Riedel et al. 2013; Brunke et al. 2020; Huemer 2020; Levesque-Beaudin and Mlynarek 2020). Development of new laboratory protocols (Prosser et al. 2016) has enabled the retrieval of barcode sequences even from old and poorly

preserved type specimens, which has helped solve some taxonomic controversies and conundrums (Kaila 2015; Mutanen et al. 2015; Buchner and Stănescu 2019).

The Barcode of Life Data System (BOLD, <http://boldsystems.org/>, Fig. 3.12), developed and maintained at the Centre for Biodiversity Genomics at the University of Guelph (Ratnasingham and Hebert 2007), is the main public platform for DNA barcode research and data storage. It acts both as a data management and analysis platform for researchers working on various projects, including taxonomic ones, and as an identification database for unidentified sequences, which can be run against the BOLD ID engine to find the closest matches in the database. Another major public resource is GenBank, which has long served as the standard global repository for nucleotide sequence data. The barcode sequence content of BOLD and GenBank are largely overlapping because sequence records from BOLD are submitted to GenBank when they are published, and DNA barcode sequences submitted independently to GenBank are frequently mined and added into BOLD. As of April 2020, 11% of COI barcodes on BOLD originated from GenBank, while 75% of the COI barcodes on GenBank derived from BOLD (Pentinsaari et al. 2020a). One major advantage of BOLD over GenBank is that BOLD allows the storage of more extensive metadata than GenBank, including images of the sequenced specimens and their morphological details.

The Barcode Index Number (BIN) system was initially introduced as an interim taxonomic system to approximate species boundaries in DNA barcode datasets consisting of largely unidentified specimens (Ratnasingham and Hebert 2013). BIN clusters are formed through a two-phase process where COI DNA barcode sequences fulfilling quality criteria are initially clustered based on a fixed threshold of sequence divergence, and these clusters are then refined through Markov clustering into the final BINs (Ratnasingham and Hebert 2013). The process is repeated on BOLD several times per year as new sequence data are constantly added into the database. BINs represent a

simplified approximation of species boundaries, but this approximation is often highly accurate. In North and Central European Coleoptera, ca. 90% of all studied species showed a perfect 1:1 correspondence with BINs (Pentinsaari et al. 2014; Hendrich et al. 2015). BINs have been widely used as a proxy for species in studies where morphological species identification of the material would be impractical or downright impossible due to the scale of the study, lack of taxonomic specialists, or largely undescribed target fauna (Young et al. 2012; D'Souza and Hebert 2018; deWaard et al. 2019). Comparing BINs to established species-level taxonomy has proved to be highly useful in revealing overlooked species diversity, new distribution records, and new synonymies among various taxa with a well-established backbone taxonomy (Mutanen et al. 2012; Landry et al. 2013; Blagojev et al. 2016).

The arthropod fauna of Canada and Alaska has been extensively sampled for DNA barcoding during the past decade both in the field and in natural history collections (Gwiazdowski et al. 2015; Hebert et al. 2016; Bouchard et al. 2017; Sikes et al. 2017; Steinke et al. 2017; Brunke et al. 2019). A handful of barcoding projects have focused on the subarctic and arctic arthropod fauna (Zhou et al. 2009; Woodcock et al. 2013; Wirta et al. 2016). The Canadian National Parks Malaise Program (<http://biodiversitygenomics.net/projects/cnp/>) targeted several arctic and subarctic national parks for DNA barcoding in 2014. The ongoing Arctic BIOSCAN project (<https://arcticbioscan.ca/>), led by CBG and funded by Polar Knowledge Canada, is aiming to build a DNA barcode reference library for the Kitikmeot region of Nunavut in order to monitor changes in the arctic arthropod fauna (Levesque-Beaudin et al. 2019; Pentinsaari et al. 2020b). No barcoding projects to date have specifically targeted North American Aleocharinae, but all the general ecological studies and biodiversity surveys coordinated from CBG, and the sampling efforts in natural history collections, have collectively added ca. 4000 DNA barcode records of Canadian Aleocharinae to BOLD.

Since 2017, representative specimens of Canadian Coleoptera BINs have been systematically

examined in order to connect unnamed sequence clusters to known genera and species, and to validate specimen identifications in cases where named species are seemingly not distinguishable based on their barcode sequences. This work has revealed multiple new distribution records in Canada and new synonymies of species shared between the Nearctic and Palaearctic regions (Pentinsaari et al. 2019). DNA barcode data also played a role in detecting some of the new synonymies established in this book (e.g., *Atheta campbelli* = *A. allocera*, *A. regissalmonis* = *A. diversa*), and revealed the occurrence of *Gnathusa caribou*, previously only known from the Nearctic region, in northern Finland.

In gathering distribution data for this book, we have used specimens in the **BOLD** database identified based on BIN assignment as basis of new state, province, and territory records for many species. These records were only accepted if representative specimens of the BIN had been identified morphologically, the BIN was not shared by multiple species, and there was no obvious reason to suspect misidentification. These records based on sequence data alone (reported as **BOLD** records in the text) are distinguished in the species treatments from those based on morphologically examined specimens.

Collection Methods and Habitats

The Aleocharinae live in almost every conceivable terrestrial habitat from alpine tundra to the intertidal zone of oceans (Klimaszewski et al. 2018, 2020). The majority of species live in forest litter and wetlands and prefer moist habitats. However, many species are more specialized and occur in fungi, carrion, and subcortical habitats. Some species are associated with mammal and bird nests. To fully sample the species at a given site, one must use various collection methods and sample over time as many microhabitats as possible. Among the commonly used collection methods are traps such as pitfall

traps, flight intercept traps, Lindgren funnel traps, Malaise traps, and light traps. Other productive sampling methods are sifting litter, treading wet or emergent vegetation in wetlands, hand collecting, and evening flight collections using an aerial net. Often the habitat will dictate the most effective collection technique(s) to use (Klimaszewski et al. 2018, 2020). Each collection technique will be discussed below.

Pitfall traps (Fig. 3.13a–b) Pitfall traps are cheap, simple to deploy, and collect a large number and diversity of Aleocharinae (and other epigeic arthropods) in many habitats, e.g., forests, fields, peatlands. They do not work well on highly rocky substrates (e.g., alvars) or in very wet substrates as the higher water table forces the trap out of the substrate. Pitfall traps may have different diameters, and there are some varieties that are commercially available. However, it is also easy to construct them from commonly available plastic containers (e.g., yogurt, ice-cream, 16 oz. beer cups). A variety of preservatives may be used (e.g., salt water, propylene glycol, 70% ethanol), and an elevated rain cover reduces dilution of the preservative and minimizes input of leaves, etc. There are many useful references about the use of pitfall traps (e.g., Martin 1977; Spence and Niemelä 1994; Skvarla et al. 2014).

Pitfall traps may be baited with carrion, dung, or decaying organic materials (e.g., fruit, vegetables) to attract diverse aleocharine assemblages associated with such substrates. Baits can be placed adjacent to the trap opening, in a small screened cage above the opening, or in a slurry of the killing agent which is later strained to remove the specimens (the latter method is less “pleasant” for sample processing).

Luminoc® pitfall-light traps use a small light built into the trap so that the trap has both a passive and active means of sampling insects. The cup is 12 cm in diameter, and lights are activated by a photocell with timer (Jobin and Coulombe 1992). The traps are commercially produced by Bio-Control Inc., Sainte-Foy, Quebec, Canada. These traps attract a greater

diversity of species than unbaited pitfall traps and often catch rarely encountered species (Hébert et al. 2000), but they are more expensive to purchase and maintain.

Collecting at lights (Fig. 3.13c) Many Coleoptera are attracted to ultraviolet light at night. The most productive light-based method for capturing Aleocharinae is to use a white sheet as a background to a mercury vapour light, which is more attractive to most insects (including Aleocharinae) than ultraviolet light. In remote sites one can power the light by a portable generator. Most Staphylinidae and Aleocharinae come to the lights from just before sunset until about 1–2 h after sunset. Specimens can be collected off the sheet using an aspirator or collected directly into the collection vial. It is best to initially place the Staphylinidae into vials with sawdust (see below) without a killing agent (e.g. ethyl acetate); otherwise many individuals will die with their wings extended. After collecting is completed for the evening, a few drops of ethyl acetate and water should be added to the sawdust to kill the specimens. This method, however, is of limited use in the North as it does not get dark enough for the light to be effective in mid summer. However, it is effective in alpine areas in more southern areas.

Lindgren funnel traps and panel traps (Fig. 3.14a) Lindgren funnel traps of various lengths (typically with 8–12 funnels) present a vertical cylindrical profile that visually mimics tree trunks, a silhouette that is attractive to many insects associated with trees (Lindgren 1983). These traps are frequently deployed with semiochemicals (e.g., pheromones, monoterpenes, ethanol) for monitoring bark and ambrosia beetles (Curculionidae: Scolytinae), and other bark- and wood-boring beetles (e.g., Cerambycidae, Buprestidae), but they are often effective for sampling many other groups of Coleoptera that are associated with dead and dying trees (Lindgren 1983). A number of Aleocharinae species in eastern Canada were captured almost exclusively in Lindgren funnel traps (Webster et al. 2009, 2012, 2016b). As these traps sample

only flying insects, they also provide useful data about flight capabilities and phenology of captured species. Traps can be suspended at any height above the ground but typically with the collecting cup at about 1.5 m (Webster et al. 2016a, c). In treeless areas one can string rope between two poles to hang traps. For details on Lindgren trap deployment, see Hughes et al. (2014). Black panel traps, a type of cross-vane trap, function in much the same way as Lindgren funnel traps and are less expensive. As well, the panels, made of corrugated plastic, are available in a variety of colours that may have differential attraction for different species. Both styles of trap are available at Synergy Semiochemicals Co., Burnaby, British Columbia, Canada.

Flight-intercept traps (Fig. 3.13d) Flight-intercept traps (or FITs) take advantage of typical beetle behaviour to drop upon hitting a barrier. FITs are typically composed of a clear plastic barrier or a tightly pulled vertical mesh barrier across a suspected flight corridor within a habitat (e.g., Peck and Davies 1980). Wide collecting trays, e.g., aluminum catering trays, are placed underneath the barrier and filled with a high concentration killing agent (see options discussed below) to prevent degradation. FITs should be serviced about once a week (more frequently in sun-exposed hot environments) to prevent the decay of fragile specimens. Aleocharines that are flight-capable can be sampled in great numbers by FITs, but it is important to take a few precautions to prevent heavily damaging specimens. First, large beetles or other insects should be removed and placed in a separate sample bag or vial. Then a fine aquarium net can be used to sieve the remaining specimens from the preservative, and these are placed into a sample container or bag already filled with ethanol. Avoid pouring the contents of the trays into the net or using a squirt bottle to wash the net as these generally create a lot of damage to aleocharine specimens. There are varieties of FITs that can be attached to tree trunks for sampling saproxylic species (e.g., Hammond 1997), and these sometimes collect species that are not collected by